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ABSTRACT

The seventh of a series of 10 study units for a Migrant Educators' National Training OutReach (MENTOR) correspondence course examines mathophobia and the special problems of language and continuity encountered by migrant children studying mathematics. Designed for use in preservice or inservice teacher education, the unit discusses testing and bad teaching as causes of math anxiety and suggests ways to deal with the patterns of misunderstanding and low self-confidence often present in mathophobic students. Excerpts from books and research reports offer perspectives on cultural background and mathematical achievement, illustrate good and bad mathematics teaching, and discuss child-centered, relevant, and natural methods for teaching disadvantaged students. Other topics include the computer as a humanizing device, relevance of outdoor education to migrant children, values teaching, and the arts as an area of basic skills. An 8-item bibliography and list of state offices of migrant education are included. (LFL)

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BOOK 7

HARVESTING the HARVESTERS

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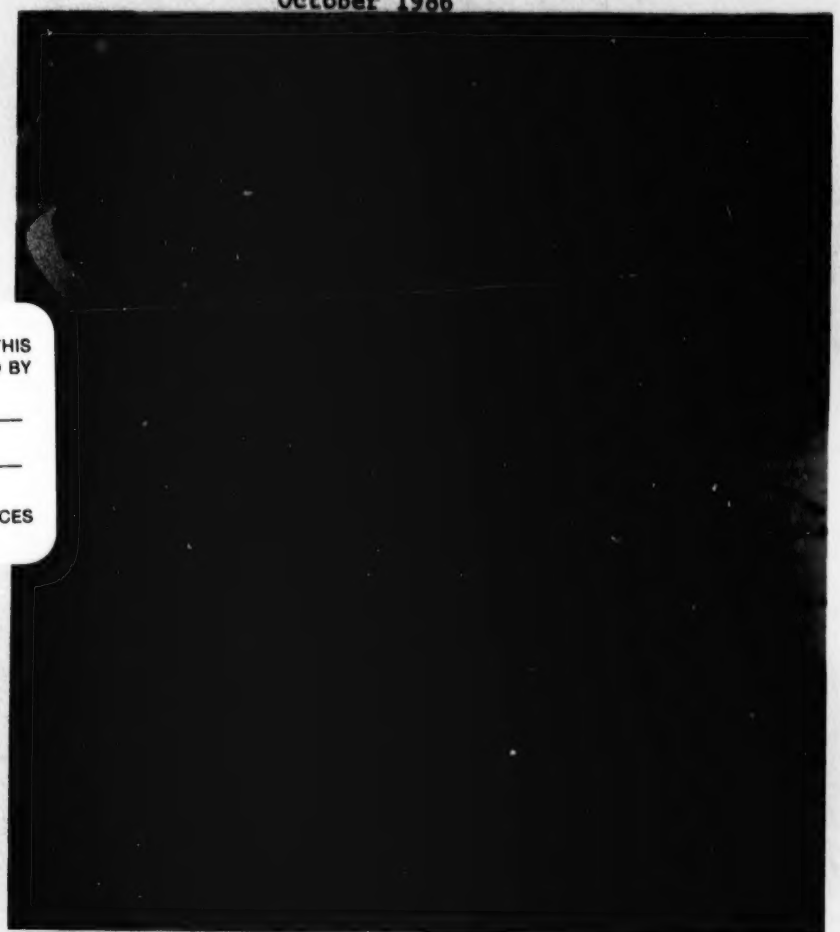
MUSIC FOR THE MIND
Mostly Mathematics, Mixed with Other Matters

October 1986



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There are two ways to teach mathematics. One is to take real pains toward creating understanding—visual aids, that sort of thing. The other is the old British system of teaching until you are blue in the face.

James R. Newman

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Mathematicians assume the right to choose, within the limits of logical contradiction, what path they please in reaching their results.

Henry Adams

Math for Migrants

Lack of continuity is the major specific problem for all migrant students, whose frequent transfers disrupt the essential patterns of the learning process. This problem is at its worst in the subject areas of mathematics. Jose Cardenas put it this way in *Inequality in Education:* "A migrant child may run into division before he encounters multiplication. As he grows up in the educational system, instead of moving from the known to the unknown, he moves from the unknown to the less known." Proper sequencing in math is virtually impossible for most migrants. They may arrive at new schools to find the students working on utterly unfamiliar material.

This is, of course, when the virtues of MSRTS and CAPM are most evident. MSRTS can establish what the migrant student has done, and CAPM can identify appropriate sections of your textbooks so you can maintain at least a rough continuity in a rational sequence. We begin this book with a familiar refrain: make the best use of the tools of the migrant network, especially MSRTS and CAPM, being certain that you keep your own records up-to-the-minute for the benefit of math teachers up and down the migrant stream.

The idea that aptitude for mathematics is rarer than aptitude for other subjects is merely an illusion which is caused by belated or neglected beginnings.

Friedrich Johann Herbart

Mathophobia

Migrants have problems beyond discontinuity. Any problems they have with spoken or written language will interfere with their ability to master math. This is a complex issue, since math is a universal language and as such accessible to individuals of every linguistic background, but students who have difficulties with English may find the jargon of math more difficult or the explanations of the teacher less clear. Most migrants are susceptible to the mathophobia that afflicts the larger American culture. "Our culture is so mathophobic, so math-fearing," says Seymour Papert. This mathophobia is as difficult to understand as it is to eliminate. The United States has always been proud of its ingenuity, its engineering, its technology, yet large numbers of Americans are made uneasy by the mere idea of math. Some groups, among them women and Blacks and Hispanics, seem statistically vulnerable to mathophobia, although individuals from these groups can be and are brilliant mathematicians if they escape the affliction of mathophobia.

Perhaps you have a touch of mathophobia yourself?

While mathophobia is imperfectly understood, it seems to be caused by the schools themselves, by the sterile teaching methods and terrifying testing practices that create a cultural environment for math that many, perhaps most children find hostile. Much of the thrust of this booklet will be to suggest ways to ease the stresses of mathophobia.

One math text listed two root causes: 1. Student knows math, but gets nervous in testing situations; 2. Student has intense dislike of math born of many causes, most prominent of which is past failures.

If you think about it, both of those are the same: the student has been damaged by testing. Testing is particularly scary in math because of the way we do it, with only one correct answer and only one chance to get it. The anxiety created by math tests accounts for a great deal of mathophobia. It is no surprise, then, that the dominant cultural group, white males, tends to suffer least from mathophobia. The wealthier the white male, the lower the susceptibility. On average, then, the self-confidence of a group, the self-esteem, the positive identity, seems directly related to potential mastery of math. Fear of failure can be a self-fulfilling prophecy, can worsen mathophobia. Given the low self-esteem of many migrants, we may expect to face mathophobia. In general, then, we must emphasize the process of problem-solving, not just the correctness of answers, and we must lavish praise on adequate work without ever belittling mistakes. These principles apply to all students, not just to migrants. Migrants, though, may be more than usually afraid of math, more than usually convinced that it is exceptionally difficult (which is not necessarily the case, at all), more than usually conditioned to fail.

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I've corrected and scored the final math tests. Looking at the low gang, I feel angry and disgusted with myself for having given these tests. The good students didn't need them; the poor students had most of whatever confidence and common sense they had picked up during the year knocked right out of them. Looking at Monica today, on the edge of tears, unable to bring herself even to try most of the problems, I felt that I had literally done her an injury. There was a lot of room for improvement in the rather loose classes I was running last fall, but the children were doing some real thinking and learning, and were gaining confidence in their own powers. What is this test nonsense anyway?

Do people go through life taking math tests, with other people telling them to hurry? Are we trying to turn out intelligent people, or test-takers? How can we foster a joyous, alert, wholehearted participation in life if we build all our schooling around the holiness of getting "right answers?"

John Holt,
How Children Fail

Advice from Migrant Educators

Elizabeth Sutton in her pioneering 1960 book *Knowing and Teaching the Migrant Child* suggested drawing math experiences from migrant experiences:

Arithmetic assignments involved actual experiences of the children and their parents. In one assignment a road map was used:

1. *A. Chart route from Michigan to the Glades.*
   B. How far was the trip?
   C. How long did you actually travel?
   D. What was the average distance traveled daily? Per hour?
   E. At an average of 11 miles per gallon, how many gallons of gas were consumed?
   F. If the average cost of gas per gallon was 31¢, what was the total gas bill for the trip?
2. *A bean grader earns 65¢ an hour.*
   A packing supervisor earns $1.05 an hour.
   A header earns 90¢ an hour.
   Each works the following number of hours during the week:

Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
9 hrs.	15 hrs.	8 hrs.	11 hrs.	14 hrs.	18 hrs.	16 hrs.

Find and compare the weekly wage of each person.

Twenty years later, Joyce King-Stoops expanded on that advice in *Migrant Education: Teaching the Wandering Ones:*

A young bank teller explained that her position was the highest attained by anyone in her family, and added, "My father worked in the fields in four states, and we were poor. But one teacher said I was good in number work, and she gave me extra help. Thanks to her, I have a good job with a great future!"

As adult citizens, migrant children will need basic mathematics for survival in their everyday life. They will need to understand mortgage and interest payments and how to figure their income tax. They will need to be able to make accurate comparisons in both buying and selling transactions if they are to become intelligent consumers and self-sustaining members of society.

The language of mathematics, like any other language, may open doors to new opportunities, far from the fields, and they need to be ready. Although reading and language instruction receive top priority in most migrant schools, effective teaching of mathematics requires a strong commitment on the part of the school and should be a carefully planned segment of every day's program.

The teacher, for example, who receives a migrant student for approximately two months' time needs to keep in mind several guidelines:

1. *On the first day, determining appropriate math placement is important. This may be done by administering a very few well-chosen test items. If a student can work two problems, he likely can do 10 of the same type. Therefore, some schools have devised short tests that have only two or three problems at each level of difficulty and that span several achievement levels, often crossing grade lines.*
2. *Teachers should try to provide individualized math tutoring, thus avoiding student frustration caused by initial failure. The "I don't get it—I don't care" syndrome is averted when the teacher or aide provides individual direction or explanation and immediate feedback.*
3. *Teachers should assume that the children will do all math work in*

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school. The migrant home rarely provides adequate facilities or direction for completing homework assignments.

4. *If the student does not speak English, provide bilingual math instruction or provide instruction in his native language. Bilingual aides may be assigned to offer explanations, give examples, and clarify work. Books and other teaching materials should be presented in the student's native language.*
5. *Teachers should present varied experiences using concrete materials to provide a basis for understanding a concept before assigning paper-and-pencil work. Measurement materials of all kinds—counters, measuring cups, balance scales, yardsticks, thermometers, and other devices—are invaluable for all learners but are especially important for a child with a language handicap. For example, one teacher taught the concept of area to a non-English speaking child by using a group activity in which students measured the area of their desks and then of the room.*
6. *After a concept is well understood, reinforce it with practice and drill. The teacher cannot rely on returning to the concept later, for the migrant child may have moved on. Teachers find that they must firmly "fix" the concept and related skills before going on to others.*
7. *Problems should begin with the children's life experiences rather than with abstract or textbook situations that may have no meaning to the migrant child. The migrant child will benefit from a rewrite of typical textbook problems into more familiar experiences. For example, one migrant teacher created math problems using cars, trucks, friends and family members, birds and animals, trees and plants, foods, and classroom situations. These made sense to the migrant children.*

Use your head to learn the subject—use the subject to learn to use your head.

G. Polya

Calm Objectivity

Allen Bernstein and David Wells in *Trouble Shooting Mathematical Skills* explain how to work with students whose repeated error patterns suggest mathophobia:

The teacher must deal with the misunderstandings which cause the pattern, and the attitudes which are both a result and a cause of the pattern. The teacher, while dealing at a symptomatic level only (deep therapy is not our business), must show that he understands how the student feels, and help to interpret to him what these feelings do to his performance. Typical helpful comments (in the appropriate situation) might be,

"Mary, you made a lot of errors because you did this so quickly. You were rushng to get this business over with and in so doing ended up making many more mistakes than were necessary. See if you won't do better by slowing down a little."

"Lee, you couldn't read these numbers back to me, even though they are in your own handwriting. Now look at the numerals in this multiplication. The columns are so crooked that you can't tell which to add where. Do you know what this tells me? You think neatness is just something to please the teacher. Let's try these examples again, and you'll see how much neatness helps."

It is evident that the feeling tones with which such remarks are made can change them from positive, constructive words to punitively charged ones which defeat the teacher's purpose. This is not a question of technique, to be learned in dramatics or elocution class. It is the more fundamental question of the feelings which the teacher has towards a particular student or category of student.

Students whose behavior patterns require this kind of assistance are often, perhaps generally, known to have deep-seated feelings of inadequacy. These may relate only to mastery of mathematics, or to school achievement in many areas. The latter are more difficult to work with, since the student has fewer areas of emotional satisfaction in school to act as compensation. In addition, reading difficulties aggravate troubles in some areas of mathematics. Such students are often convinced that they cannot learn. They will thus exhibit, at best, a kind of ambivalent behavior in which they alternate between some interest and effort, and no effort at all. They often try problems where some degree of success seems possible to them, but refuse to try if they feel sure they cannot succeed. A few will refuse to try at all. A few will exhibit antisocial behavior as a defense mechanism. Many of them are hard for the teacher to like.

The teacher needs a calm objectivity to deal with such problems, and needs, by his (her) manner, to show students that he (she) believes they can learn, that he (she) is quite confident of his (her) ability to help them, and that he (she) believes in their individual importance. This is not always easy but the rewards are well worth it. Students often show great changes in social behavior and self-confidence along with growth in mathematics.

In my math classes I am on the horns of a dilemma. I want the kids to think about what they are doing. If I make the questions too hard, they begin trying to read my mind, or, as they did this morning, they throw out wild ideas, taking all too literally my statement that a wrong idea is better than none. If, on the other hand, I break the subject down into little lumps, so that when I ask a question most of the class will be able to answer with confidence, am I not doing what I found I was doing for Ruth last year, doing most of their thinking for them? Perhaps there is no middle position, and what I must do is ask hard questions some of the time, easy questions other times.

John Holt

Sources of the Present Difficulty in Teaching Computations

Barton Hutchings contends that a basic problem with math in contemporary schools is that there is so much more to learn and no more time to teach it. Since we cannot blame any specific curriculum or text, we cannot hope some new curriculum or text will save us. We must all work harder. Period.

It is possible, without reviewing the strengths and weaknesses of individual programs, to offer a simple description of the historic forces that are producing the present difficulties. A primary cause is the rate at which human knowledge is expanding. A majority of all the scholars and scientists who have ever lived are alive and producing now.

Their work expands the mathematical disciplines on which science and technology are built, thereby increasing the number of "quantitative" professions and vocations and making existing professions and vocations more quantitative. In order to retain a large portion of their career options, children must now learn much more mathematics, since there is much more mathematics to be learned. Unfortunately, there is no extra time or energy for learning it. The great increase in mathematical concepts and generalizations in the curriculum is fundamentally in conflict with the large amount of time and energy required for the mastery of conventional computation algorithms. Moreover, increased conceptual requirements in no way reduce the requirements for computational skill, particularly in applied professions and vocations. Arguments that the new curriculum develops better understanding of the operations are beside the point. Understanding division is not the same as knowing how to divide, quickly and accurately. Each kind of learning, conceptual and computational, demands more time and attention than is now usually available. The conflict is real and critical, but it is basically the product of historic forces, not the fault of particular textbooks, teachers, or programs.

Mathematical proofs, like diamonds, are hard as well as clear.
John Locke

How Basic is Basic?

In the 19th century, the basic skills were more basic: to read, to write, and to cipher (today we would say to compute). Is that enough in the 21st century, when today's students must function? We must teach our students to compute, but is that enough? When the New Math was new, educators did not think so. Here is a statement from an elementary school text defending so-called New Math approaches:

The new developments in mathematics are one stimulus for the reform in arithmetic. The arithmetic taught in the elementary schools should relate more closely to the ideas that mathematicians of today find most useful and powerful. Specifically, this means that instruction in arithmetic should concern itself with more than computation, standard units of measure, and social and business applications, which have received so much attention in the past. Along with these topics, instruction in arithmetic should provide for the development of a meaningful concept of number, an understanding of numeration systems, the meaning of operations on numbers, the properties of number systems, and a systematic approach to problem solving. Unfortunately, mathematical ideas of contemporary interest have been introduced only recently into the arithmetic program. Schools are just now beginning to bring the arithmetic program up to date so that it more nearly reflects the mathematician's view of mathematics.

The schools must realize that learning to compute is not the only—or, indeed, the most important—purpose of studying elementary-school arithmetic. Of course children must know how to compute, but computation is important only as a means to an end. The ability to compute assists children in arriving at generalizations about numbers; but, in the end, it is the generalizations and abstractions that are of primary importance.

Critics of New Math liked to say that high school graduates could not even make change. A student who only knows how to make change has been short-changed. Computation must be learned in the larger context of numbers and how they work. Yes, your migrant students need basic math, but keep in mind that the basic math of the 21st century will be pretty sophisticated compared to the arithmetic of the one-room schoolhouse of the 19th century.

Looking Back

In their haste to go on to another problem or some other work, teachers and children may fail to look back at the analysis and solution of a problem. This is unfortunate. Capitalize on their feelings of accomplishment to review the procedures used in solving the problem. Stopping when an answer is obtained gives undue emphasis to the importance of answers. Take a few moments after a problem has been solved to reflect on the plan used to solve it. Here is where you can reinforce such techniques as careful reading, drawing pictures, organizing guesses, using easier numbers, and reading carefully to be sure of what is known and what we need to find. After all, these are the very things we want children to do when they meet up with story problems or any application of mathematics. When looking back, be sensitive to other ways to solve the problem. Encourage and reinforce children's efforts to analyze problems. You may find looking back to be your most effective technique in teaching children to solve problems.

Edward J. Davis
& William D. McKillip

Culture and Math

As a universal language, mathematics ought to transcend cultural differences but in a curious way it does not. While individuals from any culture may become brilliant mathematicians, some groups are more apt to excel than others. Consider the case of the Vietnamese Boat People.

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During the early and mid-70s, when the North Vietnamese took control of South Vietnam, about half a million Vietnamese refugees, nicknamed the Boat People, came to the United States, where nearly half settled in California. Most knew little or no English; most were poor, even if they had been well-to-do in Vietnam. They shared, therefore, some key attributes with many migrants: poverty, Limited English Proficiency, cultural alienation.

Today the children of the Boat People are doing very well in American schools and colleges, especially in math and science. They shy away from the Humanities because their continuing problems with English seem to preclude their reaching the very top ranks in those fields. Asked by a PBS interviewer why they did so well in math, one Vietnamese American responded, "Because it is a universal language."

True, but it is universal for all Americans, many of whom are mathophobic. Some of the explanation for the success of the Vietnamese lies in their confidence that Asians can master math. They expect themselves to do well. They also work very, very hard. One white American told the PBS interviewer that the Vietnamese were "gnomes," grinds and bookworms who did not socialize but studied, studied, studied, and studied some more.

No easy generalizations can be drawn from the example of the children of the Boat People. They prove that poverty and Limited English Proficiency do not necessarily result in low math scores, and that hard work pays off in the study of math. Their example robs us of any excuses we might make for ourselves as migrants or Migrant Educators. Math can be mastered by people who are poor and have limited English, if they have self-confidence and work hard.

Poor teaching leads to the inevitable idea that mathematics is only adapted to peculiar minds, when it is the one universal science and the one whose four ground-rules are taught us almost in infancy and reappear in the motions of the universe.

H.J.S. Smith

Child-Centered, Relevant, Natural

Robert Davis feels that the methods appropriate for the disadvantaged are the same as those for the advantaged: child-centered, relevant, and natural. He does feel that most attempts at remediation have been unimaginative, featuring more-of-the-same with added "fervor and determination." For the record, "fervor and determination" are not bad attributes for remedial math teachers. This is what Newman calls "the old British method of teaching until you are blue in the face," what Owen calls the "tough, no-nonsense approach," what works so well for the Vietnamese students in California. Here is Robert Davis on math teaching for the disadvantaged:

The Non-achiever, the School Dropout, and the Culturally Disadvantaged

Obviously, another source of pressure on the curriculum comes from the increased recognition that far too many children get off to an impossibly bad start in life. We shall not discuss this as a separate issue, because the need here—for a more child-centered school, a more intelligible and relevant program of school activities, a more effective use of the child's natural modes of learning, and so on—is basically the same as the need for improved education for all *children. But if this is not a separate problem, it does represent a separate and recognizable source of pressure on the schools.*

Most attempts to improve "general mathematics" (or secondary school mathematics for low achievers) tend to be unimaginative. The same content is taught in more-or-less the same old way, but with added fervor and determination. By contrast, a few attempts have been far more creative and imaginative. Most of these "imaginative" programs have varied the content, often trying a wide variety of mathematical topics in the hope of striking some spark of interest; many have also used physical materials, ranging from Cuisenaire rods to desk calculators and even to electronic computers. Some have used teaching machines. Some have manipulated the classroom environment (in some cases shifting it away from its usual middle-class tone). Some have sought to teach "harder" material rather than "easier" topics. Some have abandoned traditional sequences of topics—for example, by moving on to analytic geometry and algebra rather than continuing the uphill battle with arithmetic. In some cases, the mathematics is tied to vocational courses in the operation of a television studio or courses in wiring and operating digital computers.

Surely it is only reasonable to say, on present evidence, that people do seem to be shaped by their education, and that many non-mathematical aspects of behavior are presumably influenced by (among other things) the manner *in which one encounters mathematics,*

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and by the types of experiences one accumulates, whether in the mathematics classroom or elsewhere.

Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write.

H.G. Wells

Bad Teaching

Here are two examples of classroom teaching deplored by educators who love math. The first is a famous excerpt from John Holt's *How Children Fail*; the second is from Robert B. Davis's *The Changing Curriculum: Mathematics*.

The other day a lady said for me, better than I ever could have said it for myself, just what is wrong with the whole school setup. During this past vacation I visited a school that was still in session. It has the reputation of being very "good" and "tough." The headmistress, who was very nice, asked me where I had taught. When I told her, she said with false humility, "I'm afraid you'll find us very old-fashioned." But she made me welcome, and particularly urged me to visit the arithmetic class of her fourth-grade teacher, who had been there for many years and was generally felt to be a jewel among teachers and the pride of the school. I went. Soon after I arrived the class began. The children had done some multiplication problems and, in turn, were reading answers from their marked papers. All went smoothly until, right after a child had read his answer, another child raised his hand. "What is it, Jimmy?" the teacher asked, with just the faintest hint in her voice that this interruption could not be really necessary. "Well, I didn't get that answer," said Jimmy, "I got . . ." but before he could say more, the teacher said, "Now, Jimmy, I'm sure we don't want to hear any wrong answers." And that was the last word out of Jimmy.

This woman is far ahead of most teachers in intelligence, education, and experience. She is articulate, cultivated, has had a good schooling, and is married to a college professor. And in the twenty years or more that she has been teaching it has apparently never occurred to her that it might be worth taking a moment now and then to hear these unsuccessful Jimmies talk about their wrong answers, on the chance that from their talk she might learn something about their thinking and what was making the answers come out wrong. What makes everyone call her such a good teacher? I suppose it is the ability to manage children effortlessly, which she does. And for all I know, even the Jimmies may think she is a good teacher; it would never occur to them that it was this nice lady's fault that they couldn't understand arithmetic; no, it must be their own fault, for being so stupid.

The mathematics classroom of recent years has been one of the most culturally-deprived environments inhabited by any American child; it has offered little beyond blackboard, chalk, pen, paper and textbook. What is worse, the plot has been as barren as the scenery: in one high school of good reputation a teacher recently spent two consecutive 45 minute periods writing examples like this

$$x^2 \cdot x^5 =$$

on the blackboard and going around the room, letting each child in turn give an answer to a question of this type:

$$x^2 \cdot x^5 = x^7$$
$$p^2 \cdot p^{10} = p^{12}$$
$$x^3 \cdot x^2 = x^5$$
$$x^2 \cdot x^6 = _____$$

and so on. She construed that she was "teaching exponents," but her methodology was straight out of Pavlov, and may possibly be the proper way to teach algebra to dogs. Human children "conditioned" this way learn so well that they come to college, see

$$x^2 + x^5 = _____,$$

and respond (quite incorrectly) by saying "x^7," as many a college mathematics teacher can testify.

The kind of school we shall have if we move into the era of computerized instruction with this kind of primitive pedagogical philosophy staggers the imagination.

To understand the educational inadequacy I am trying to describe, one need only compare a child at play with that same child sitting in class during a mathematics lesson.

The whole of mathematics consists in the organization of a series of aids to the imagination in the process of reasoning.

Alfred North Whitehead

Good Teaching

If Pavlovian conditioning and a regimented classroom aimed at producing correct answers constitute bad teaching, then good teaching must find ways to bring math to life while emphasizing the process of working toward correct answers. We cannot explore all the ways to do this on every level, from introducing numbers to pre-schoolers to establishing important arithmetical concepts in the primary grades through fractions and decimals to algebra and geometry. If you have specific problems, call us or others in the migrant network for specific advice about materials and methods.

We assume you are not a professionally-trained math teacher. Most people reading this will be working in tutorial situations with students who need remediation. Much of what you may find yourself doing will consist of routine drill to get your kids past some standardized test. They deserve more, though, and you must take the initiative in seeing that they get it. Two useful books will be Herbert Kohl's *Math, Writing, and Games in the Open Classroom* and John Holt's *What Do I Do Monday?* They can give you a positive attitude toward the teaching of math that you will need working with a population all too likely to have a negative attitude toward the subject.

Holt taught math in the primary and middle grades. He obviously loved it, bringing an enthusiasm that can only help the atmosphere of a math classroom. What Holt liked about teaching math was its many opportunities to *do* things, to use things, to get the students out of their seats and into an activity. He liked to use tape measures, pocket calculators, metronomes, sphygmomanometers (used to measure blood pressure), GSR meters (to measure Galvanic Skin Response), Cuisenaire rods, stopwatches, exercise equipment, scales, all manner of things from the familiar and workaday world to make math alive and meaningful.

Here is a sample of Holt's thinking: "I don't think children should be 'taught' fractions, but that instead they should meet and work with them in the course of their real work with numbers. If we feel we must try to 'teach' children fractions, the proper time to begin is in the first grade. It is a dreadful mistake to wait until fourth or fifth."

Holt is always provocative, whether you agree with him or not. He warns

against the belief that some method or other will produce spectacular results. "This Gifted Teacher is a myth. The hard fact is that we teachers have low batting averages. A baseball player is doing well if he gets three hits in ten tries. A teacher does well to get one hit in ten tries, or even twenty. Teaching is human communication, and like all communication, elusive and difficult. We must learn from the children. And learn afresh every year: children and classes are different; what went wonderfully one year may not go well the next. In fact, we must be wary of the feeling that we know exactly what we are doing in a class. When we are most sure of what we are doing, we may be closest to being a bore."

It is time that we resolve to seek much deeper discussions of what schools, mathematics, and children have to do with one another.
Robert B. Davis

Getting It Right the First Time

A fundamental flaw in virtually all math tests is that they reward only correct answers, giving a false impression of what both life and math are all about, which is how to work out problems until a correct response is found. Christopher Strachey favors tests that give students three or four chances to get the correct answer, or group tests where the majority agree on a correct answer while those who disagree file minority reports. Lewis Anthony Dexter in *The Tyranny of Schooling* (1964) advocated such methods.

Strachey wants teachers to test the ability to arrive at a satisfactory result with the help of an intelligent critic. He points out that the brilliant mathematicians who helped develop early computer programs were aghast to have the machines demonstrate how many careless errors in computation they made. Why should a child be held to a higher standard than an adult mathematician?

In the early days of computer programming—say 30 years ago—mathematicians used to think that by taking sufficient care they would be able to write programs that were correct. Greatly to their surprise, and chagrin, they found that this was not the case and that with rare exceptions the programs as written contained numerous errors. The process of discovering, locating and correcting these errors proved to be one of major difficulty, often taking considerably longer than writing the program in the first place and using a great deal of machine time.

Although programming techniques have improved immensely since the early days, the process of finding and correcting errors in programs—known, graphically if inelegantly, as "debugging"—still remains a most difficult, confused and unsatisfactory operation. The chief impact of this state of affairs is psychological. Although we are all happy to pay lip service to the adage that to err is human, most of us like to make a small private reservation about our own performance on special occasions when we really try. It is somewhat deflating to be shown publicly and incontrovertibly by a machine that even when we do try, we in fact make just as many mistakes as other people. If your pride cannot recover from this blow, you will never make a programmer.

It is not, in fact, in the nature of human beings to be perfectly accurate, and it is unrealistic to believe they ever will be. The only reasonable way to get a program right is to assume that it will at first contain errors and take steps to discover these and correct them. This attitude is quite familiar to anyone who has been in contact with the planning of any large-scale operation, but it is completely strange to most people who have not.

The trouble, I think, is that so many educational processes put a high premium on getting the correct answer the first time. If you give the wrong answer to an examination question, you lose your mark and that is the end of the matter. If you make a mistake in writing your program—or, indeed, in many other situations in life outside a classroom—it is by no means a catastrophe; you do, however, have to find your error and put it right. Maybe it would be better if more academic teaching adopted this attitude also.

It is an old maxim of mine that when you have excluded the impossible, whatever remains, however improbable, must be the truth.
Sherlock Holmes
The Beryl Coronet

Math in the Average High School

David Owen was a young Harvard graduate who decided to enroll as a student in an average American high school. His 1981 book *High School* is part cultural anthropology, part nostalgia trip. Here is the chapter about his math class. Perhaps the key passage for our purpose is this: "He had the tough, no-nonsense approach that is

the stock in trade of successful high school math teachers. Math could be conquered by sheer persistance—that was the impression he gave. You didn't have to be a genius, you just had to make the effort." The chapter is a useful visit to a real classroom.

Back in the eighth grade, when I took my first algebra course, one of the guys in my class was baffled for most of the first week. He just couldn't figure out what x was supposed to be. He tried everything he could think of but he couldn't get it to work out the same two times in a row. Seemed like x had a different value in every equation he tried. Our math teacher could scarcely find words to explain what was the matter.

I was never quite so lost as my friend was, but even so I did not have an easy time in math. I couldn't seem to understand anything until after we had been tested on it. In eleventh grade, while most of my friends dug into their first year of calculus, I signed up for a gut course called "Pre-Calculus," which was really just a simplified rehash of the Algebra II I had taken the year before. The next year I took no math at all and felt warm all over when I realized I would never have to take it again.

I was quite surprised, therefore, when I found myself enjoying Advanced Math at Bingham. Suddenly algebra was making sense to me. At home I started taking my math book to the dinner table and doing my homework while I ate. It drove Ann crazy, but I felt as though a veil had been lifted from my eyes. My original plan had been to do no homework at all in any of my classes, except when I had an assignment that had to be handed in. I figured it would be easier to put in an "average" performance if I didn't know the material and had to guess than if I did know it and had to decide what sort of responses would be appropriate for a high school student. In English and history I looked at my books only enough to determine what was being covered, and then relied on whatever I could remember from college and high school. Which wasn't usually very much. But in math I was completely carried away. My new feel for a discipline that had always eluded me gave me an enthusiasm I found difficult to control. I was even doing the extra-credit problems, although I didn't hand them in. And then, on our first test, I got the highest score in the class.

I felt guilty about doing so well, but even though my grade was the highest it wasn't terribly good, all things considered. I got 54 points out of a possible 60, which works out to 90 percent. Since the test was intended merely to see how much we remembered from Algebra II, which all of my classmates had taken the year before, I figured everybody would do well. But no one did. The next highest grade after mine was 40 points, or 66 percent, which at Bingham was just one point above passing (in math, as in most of my classes, our grades were often read aloud).

Oddly enough, my classmates' difficulties on the test were more verbal than mathematical. The quiz dealt solely with definitions of basic algebraic terms, and the concepts it covered were the sort that are disposed of in the introductory chapters of all algebra books. Anyone with even vague recollections of Algebra II ought to have been able to figure out most of them, and this was a class of good students. Advanced Math was limited to kids who had earned grades of B or higher in Algebra II. They weren't the most advanced students in the school—those were the ones taking calculus—but they were near the top. Their main problem on the test was in expressing clearly what by now they knew more or less intuitively.

One of the questions on the test asked us to define a "product." I wrote, "X is a product if there are real numbers A and B so that $A \times B = X$," which is more or less right. I hadn't memorized that definition, but with a little thought I was able to figure out what it ought to include. I knew it would have to be specific enough to be binding and yet

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general enough to cover all the possibilities. It was an easy question and everyone should have been able to come close. But the vast majority of my classmates defined product simply as "answer." They had similar difficulties with almost all the questions. The first one was a fill-in-the-blank, "A set is a _____ of _____ objects." The proper answer is, "A set is a group of well-defined objects." I didn't quite have that, but I came close enough to receive credit. Most of my classmates, though, were way out in left field (even to the point of ignoring that the word "objects" had been supplied): "A set is a set of various objects"; "a set is a pair of brackets"; "a set is a number of things"; "a set is a group of numbers"; "a set is a set of subsets."

People who worry about the continuing decline in SAT scores almost always treat the drops in the math and verbal parts as separate phenomena. But in my math class, mathematical difficulties were very often verbal in origin. Several students referred to mathematical variables (X and Y, for example) only as "letters." I heard one boy refer to exponents, the superscript numerals in expressions like "X^3 or "$E = mc^2$," as "them little numbers." A student who can't find words to express basic mathematical principles is handicapped before he even tries to attack a problem.

Some of the class's difficulties could be traced directly to our textbook, which was written in such harrowing language that even our teacher had trouble deciphering it: "The sign of a signed numeral is the sign that precedes it or is understood to precede it"; "We shall deal with those nonlinear inequalities whose left members can be factored into linear factors and those that are fractions with the unknown in the denominator and probably also in the numerator." Textbook publishers compete so fiercely with one another for the limited (and shrinking) markets that they continually throw out good books in favor of new editions too hastily put together. The authors of our text had apparently felt so compelled to be different that they had abandoned a number of standard terms and replaced them with new ones that were supposedly more logical or meaningful. As a result, a lot of my classmates found themselves in the dark a good deal of the time. The very vocabulary of algebra had shifted beneath them.

Mr. Pottle, our teacher, made a valiant effort. "These books are actually college-level," he told us, "and they're more confusing than they have to be, but there's nothing we can do about that until they wear out." Mr. Pottle eventually abandoned the book, except as a source of homework problems, and gave us mimeographed handouts explaining the explanations in the chapters. "We used to have a great book in this course," he said, "but you can't buy it anymore. They took it off the market."

Mr. Pottle reminded me so much of one of my high school math teachers that twice I called him by the other man's name. He had the tough, no-nonsense approach that is the stock in trade of successful high school math teachers. Math could be conquered by sheer persistence—that was the impression he gave. You didn't have to be a genius, but just had to make the effort. He wrote everything out on the blackboard in huge, legible script and checked over our computations on homework assignments so meticulously there could never be any doubt where a problem had gone wrong. Most of the kids in the class thought he was too hard—Amy Kendris told me she could never understand any of his explanations—but almost everybody liked him. When he was sick for two weeks and we had a substitute fresh out of college, the complaints were immediate.

"That's not the way Mr. Pottle does that," Amy said.

"I'm not Mr. Pottle," the woman said.

"No, you're not."

Almost everyone stopped doing homework while the substitute was there (even I did). She kept trying to give metaphorical explanations of mathematical principles in the book—"Try to think of a function as a vending machine"—but no one was interested. When Mr. Pottle finally returned, he got a reception he couldn't have expected.

"That substitute lady thought she was Young Miss College Professor, man," Greg Liszk said.

Mr. Pottle was unflatterable. "You don't seem to have done a whole heck of a lot of work while I was out," he said. "There's a lot of material we're going to have to make up."

"She had all these teaching methods," Greg added.

In addition to his Advanced Math sections, Mr. Pottle taught a course in remedial math for kids who were having trouble with computation and basic concepts. "I had to spend five minutes this morning convincing them that

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eleven times eleven is a hundred and twenty-one and not a hundred and eleven," he told us one day. "The trouble with New Math, which is what you and everybody else in the country studies, is that it doesn't pay attention to the basic operations, like addition and multiplication. Back in the Stone Age when I was in school, you had to know what eleven times eleven was. You had to learn multiplication tables. Now they give you a handful of different-colored sticks and worry more about whether you know what base three is than whether you can add and subtract."

Mr. Pottle's remedial course was designed for the victims of New Math. "What a zoo that class is," he said. "I don't want you folks to get the impression that you don't give me headaches—believe me, you do—but compared with those guys, coming into this class is like dying and going to heaven."

"We're angels, right, Mr. Pottle?" one of the girls said.

"Or something," he said. "The hardest thing with the remedial group was just getting them motivated. The level they need the real help at is so elementary that they laughed when I gave them their first assignment. They said, 'Man, we don't need this stuff. It's easy.' Then they did the problems and I'd say on the average they got maybe ten percent of them right. So I went over to one of the big department stores and got a big stack of job applications from their clerical department. The forms had a little mathematical computation section, because you need some dexterity with figures to do that kind of work. Next day I handed out the forms in class and had the kids all fill them out. Then I gave them to my brother-in-law, who's the district representative of a large corporation, and asked him to read and critique them. I told him to say whatever he thought, to react as though he was actually reviewing applicants for a beginning position. The guy was merciless. Then I brought them all back and handed them out without comment, and from then on I didn't have any trouble."

A couple of the boys laughed.

"Laugh while yet ye may, ladies and gentlemen," Mr. Pottle said. "I've been thinking about making another trip over to that store."

People who don't count won't count.

Anatole France

The Computer as a Humanizing Device

Robert Davis points out that, properly used, the computer can individualize learning by allowing the child to proceed at his or her own pace:

Small-group instruction, seminar-type discussions, and a student-centered school atmosphere are not incompatible, by any means, with the use of computer-assisted learning devices. As Professor Suppes points out, they are in fact complementary, and directed toward basically similar goals—such as rescuing the individual child from the anonymity of being one of 30 children to whom the teacher is talking, or one of 100,000 children for whom a textbook was written.

Regarding computers in public education, it is my basic view that as soon as children are in schools they should have opportunities to program computers to solve mathematical problems.

Richard J. Shumway

Science

One of the beauties of science is that it defies cultural differences. The laws of physics ignore ideology or language, being the same in Soviet Russia as they are in the United States of America or Switzerland. Great scientists have been produced in Arabia and Poland and England and America. There are few new techniques required to teach science to migrants.

One approach that has proven successful is outdoor education. Summer programs and the regular school year can be enhanced by moving the classroom to the great outdoors, where some migrant children may feel at more ease than in the confines of a classroom. These techniques have proven themselves. They may or may not be appropriate for your situation. If they are, or if you think they might be, here are two new books to seek out:

Get the spark back into your classroom! Use the outdoors to enhance math and science curriculum.

The ERIC Clearinghouse on Rural Education and Small Schools is pleased to announce the publication of two new resource guides which enhance the teaching of mathematics and science through the use of outdoor education methodologies.

Using the Outdoors to Teach Science: A Resource Guide for Elementary and Middle School Teachers *(49pp., $5.50) assists teachers of grades K-8 in developing activities to enrich science in-*

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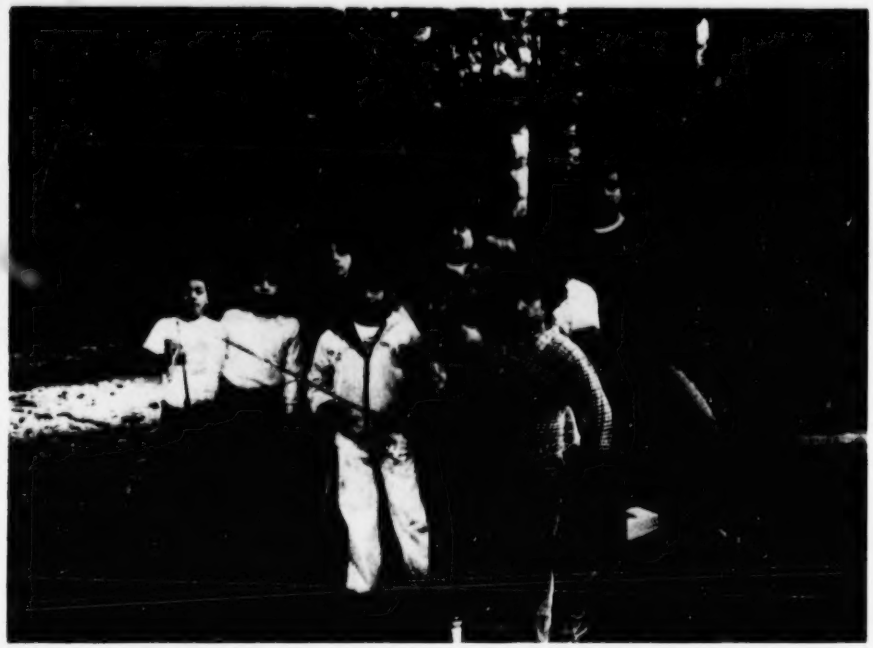


struction. The introductory sections define outdoor education and provide a rationale for outdoor science teaching, stressing the opportunities it provides for creativity, inquiry, and problem solving. The majority of the guide is made up of detailed plans for outdoor science activities on the school grounds or other easy access outdoor sites.

Using the Outdoors to Enrich the Teaching of Mathematics *(65pp., $5.50) suggests ways of getting students interested in mathematics and arithmetic and how to make teaching math fun. The 15 outdoor activities are keyed to the basic mathematics skills which the National Council for Teachers of Mathematics (NCTM) advocates each student to acquire before completing high school. Each lesson is presented as an "idea" and contains descriptions of the NCTM skill, purpose, materials required, specific activity, and procedures.*

The author, Dr. Milton Payne, brings to these works 20 years of experience in the areas of education, outdoor education, middle school teaching, and individualized instruction.

The guides are available from the ERIC Clearinghouse on Rural Education and Small Schools, Publications Dept. 16, New Mexico State University, Box 3AP, Las Cruces, NM 88003. Price: $5.50 each. Prepayment or purchase order required—U.S. currency only.

You can bring the outdoors in with a live natural science corner. This is from McCaffery:

As children are quite naturally interested in animals, the inquiry approach may be developed through an 'alive' science corner. Gerbils, turtles and fish offer a child an opportunity to develop his observation skills. His role in caring for the animals will nurture his sense of responsibility.

Individual terrariums with collected mosses placed in a jar are simple yet fascinating to the child. Children enjoy planting seeds of their own in eggshells. As the seeds germinate and grow, a child may begin to develop his scientific understandings by recording his observations of what is happening to the seeds. Math learnings concerned with time and measurement could also originate from the child's recordings of plant growth.

The advantage of outdoor education for migrants is obvious. For once, the classes are conducted on their turf. Even a classroom terrarium can link their school lives to their experience with growing things.

George Dennison recommends the teaching of science with everyday machines:

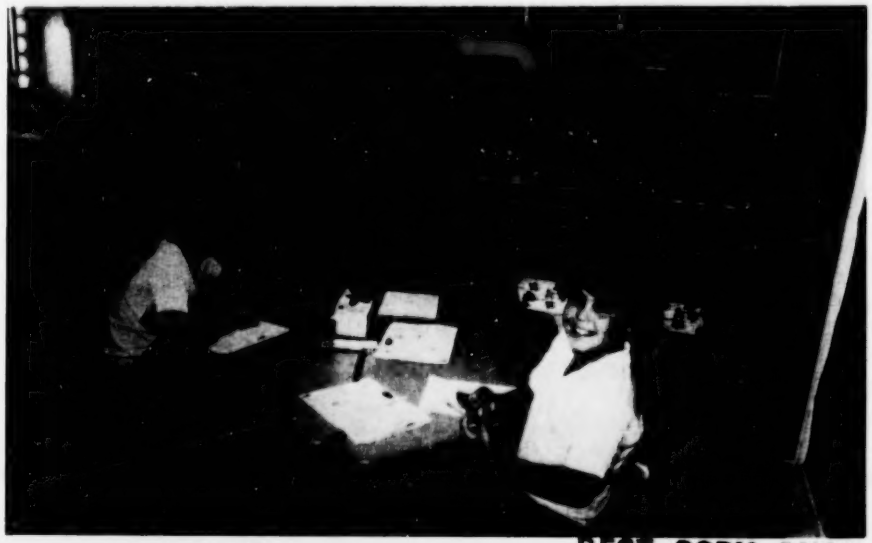
Excellent science materials can be found in junkyards and surplus stores —old gas-pump meters, random electronic parts, discarded TV sets, gyroscopes, and tape recorders are all very helpful. I have seen them used to produce and duplicate stories and cartoons and newspapers, to record conversations, and to make fanciful explorations of unusual sound and color phenomena. It is important that they be introduced to the children in such a way that they can be used as soon as possible without adult supervision.

But there is another reason for the high repute of mathematics: it is mathematics that offer the exact sciences a certain measure of security which, without mathematics, they could not attain.

Albert Einstein

The Social Sciences

What schools tend to call Social Studies or Civics or History are in fact social



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sciences, so called because we want to study society with some of the precision and rigor we use to study the natural world. History, Economics, Political Science, Anthropology, Sociology, all are involved in the lessons of every school.

As a Migrant Educator, you may find it useful to develop your own material in these areas, from the media and from materials about the lives of migrants that illustrate principles you seek to elucidate. These things can usefully supplement standard texts.

Migrant children need the skills of good citizenship as much as their more sedentary peers. They need to know how the world works and they need to know how to express the creative and imaginative aspects of their personalities.

Every school affords a rich choice of materials for social studies. George Dennison in *The Lives of Children* urges you to create your own:

It's best to make a social studies program for yourself, building it around the children in the school, how they relate to each other, how they solve or fail to solve problems arising in their own social group. Films can often be helpful here, as can live—not educational—TV, especially at times when the children's interest is high, as at the launching of space craft.

Many critics charge that American education does not teach values. These critics usually mean that the schools do not stress their particular value preferences, or even their sect's dogma, things it would be inappropriate for the schools to do. The schools teach values all the time, by example, by the things they choose to do and the ways they choose to do them. We all want to confer a respect for democratic traditions upon ensuing generations. We want them to know how wonderful the Bill of Rights and our tradition of individual liberties are. Teachers must realize that the manner of their teaching is at least as important in this regard as the matter being taught. Put simply, you cannot teach democratic values in an authoritarian classroom. In an authoritarian classroom, you can only teach respect for and/or resentment of authority. You must achieve a delicate balance between maintaining the authority every teacher needs and deserves and creating a democratic atmosphere of respect for differences of opinion.

The manner of presentation is as important as the matter being presented in math and science, too. A tolerant, open, low-stress classroom is best for arithmetic, best for social studies.

Through and through the world is infested with quantity: To talk sense is to talk quantities. It is no use saying the nation is large—How large? It is no use saying radium is scarce—How scarce? You cannot evade quantity. You may fly to poetry and music, and quantity and number will face you in your rhythms and your octaves.

Alfred North Whitehead

The Arts

This is the end of our look at The Basics, customarily limited to Reading, Writing, and Arithmetic. Some contend that these so-called Three R's need a Fourth R—Art. In his book on basic skills, Herbert Kohl insists on including the arts:

Another priority is the acknowledgement of the arts as basic skills. *Whether through the development of centers of expression or through changes on a school or local level, arts programs should be established and given the same status as language, mathematics, and science programs. Not every school can manage to cover all the arts from music to film-making, but not every literary genre can be covered in English either. One must choose one's art program carefully, balancing community desires with staff talent and community resources, and then make a major commitment to develop and support a locally designed program. One school might choose music and dance with lesser emphasis on the visual arts, while another might choose painting, drawing, sculpture, and woodcarving. These selective emphases are necessary short of having comprehensive art centers, just as the choice of books is necessary in language and the choice of period and location to study is necessary in history.*

What is probably going to be the greatest problem in developing these programs is getting people to think of art as basic to decent public education. The art-as-frills mentality has to be confronted directly and we have to insist that the skills and the pleasures derived from the arts not be reserved for a privileged few but are owed to all children.

Migrant children deserve the best education available in every subject. They need basic skills, yes, just as everyone does: as tools to begin the great adventure of education, not as ends in themselves. Most migrants are economically deprived. They must not be educationally deprived, too.

Mathematics is music for the mind; Music is mathematics for the soul.

Anon

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Suggested Readings

Davis, Robert B. *The Changing Curriculum: Mathematics.* NEA Association for Supervision and Curriculum Development. 1967.

ERIC/CRESS. *Migrant Education: A Selected Bibliography* (with ERIC abstracts). Las Cruces, New Mexico: ERIC/CRESS, 1977.

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Videotapes

Teaching Mathematics Effectively. Association for Supervision and Curriculum Development, 1983. ASCD members, $195. Non-members, $230.

Arithmetic is where the answer is right and everything is nice and you can look out of the window and see the blue sky—or the answer is wrong and you have to start all over and try again and see how it comes out this time.

Carl Sandburg

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